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New records reveal rapid geographic expansion of *Bombus terrestris* Linnaeus, 1758 (Hymenoptera: Apidae), an invasive species in Argentina

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Abstract: *Bombus terrestris* Linnaeus is an invasive bumblebee in Argentina. Since its first record in March 2006, *B. terrestris* has rapidly become the most widespread species in the southern Argentina's Patagonia. The explosion of *B. terrestris* populations has been associated with the rapid decline of the unique native species *B. dahlbomii,* Guérin-Méneville. However, *B. terrestris* had never been yet reported farther south than the 50° parallel. We report for the first time the presence of *B. terrestris* at the southern end of continental Patagonia and discuss its meaning with regards on potential consequences for *B. dahlbomii* populations.

Key words: *Bombus dahlbomii*, invasive bumblebee species, Patagonia

Argentina has eight native bumblebee species (Abrahamovich and Diaz 2001). However, only one native species occurs in the southern Argentina's Patagonia, *Bombus dahlbomii,* Guérin-Ménéville, 1835 (Abrahamovich and Diaz 2001; Abrahamovich et al. 2007). This large generalist bumblebee plays a key role in ensuring reproduction of many native and endemic plants of the temperate forests of the Patagonian region (Morales and Aizen 2002; Montalva et al. 2011).

Two introduced European bumblebee species have invaded this region, however. *Bombus ruderatus* (Fabricius; 1775) and *B. terrestris* (Linnaeus, 1758) were recorded for the first time in Argentina's Patagonia in 1993 and 2006 respectively. These two invasive species probably entered Argentina through low-altitude passes across the Andes (Roig-Alsina and Aizen 1996, Torretta et al. 2006) from Chile, where they were introduced for crop pollination in 1982–1983 and 1998 respectively (Roig-Alsina and Aizen 1996; Torretta et al. 2006). Bumblebees in general are considered valuable crop pollinators and *Bombus terrestris* in particular is a suitable species for rearing and transport in nesting boxes, so is used to provide pollination services worldwide, even in regions where it is non-native (Lye et al. 2011).

In 2011, a comprehensive survey was carried out to assess *B. terrestris, B. ruderatus* and *B. dahlbomii* populations in Argentina's Patagonia (Morales et al. 2013). This study included the entire geographic range of *B. dahlbomii* along the eastern slope of the Andes, ascertained based on a comprehensive review of museum records (Abrahamovich and Díaz 2001). The survey documented a rapid expansion of *B. terrestris* populations, both in abundance and geographic range (Morales et al. 2013). Five years after it was first recorded, *B. terrestris* had become the most abundant and widespread species, and was observed approximately 650 km further south than it had been reported for the last time (Montalva et al. 2011). In contrast, populations of the native *B. dahlbomii* declined drastically, completely disappearing from several locations where they were replaced by invasive bumblebees, in particular *B. terrestris* (Morales et al. 2013). This dramatic decline has been strongly linked to the presence of the invasive *B. terrestris*, probably due to a combination of competition for resources and horizontal transfer of pathogens from *B. terrestris* to *B. dahlbomii* (Arbetman et al. 2012; Morales et al. 2013), a hypothesis that should be tested.

In 2011, not a single *B. terrestris* was recorded farther south than the 50° parallel, during 4-hour walk transects (Morales et al. 2013) or during the rest of the time spent in the area (in total 4 days, Morales, pers. obs.). Further in the south than this point, *B. terrestris* was virtually absent, thus leaving refuge areas for *B. dahlbomii* populations, which were still present in 2011 (Table 1; see also Morales et al. 2013). However, this report indicates new records of *B. terrestris*, 300 km further south than the survey of 2011, indicating an

Table 1. Records of *B. dahlbomii* and *B. terristris* individuals in the surveys of 2011 (see methodological details in Morales et al. 2013) and 2014 (see Material and Methods). The number of individuals recorded (total) and the duration of observations (hours obs.) are provided for each site.

	Bombus dahlbomii				***Bombus terrestris***					
	2011		**2014**		**2011**		**2014**		**Latitude (S)**	**Longitude (W)**
Location	**Total**	**hours obs.**	**Total**	**hours obs.**	**Total**	**hours obs.**	**Total**	**hours obs.**		
Camino a Lago del Desierto	27	4	0	4	1	4	>10	6	49°16′24″	072°64′32″
El Chalten	26	4	0	4	1	4	0-5	6	49°33′05″	072°88′54″
El Calafate	16	4	0	4	0	4	>20	4	50°31′21″	072°80′48″
Glaciar Perito Moreno	9	4	1	0.33	0	4	0-5	3	50°46′35″	073°02′38″
Rio Gallegos	NA	NA	0	0	NA	NA	0-5	3	51°37′20″	069°12′50″

important expansion of its geographic range.

The morphological differences between *B. dahlbomii* and *B. terrestris* make them easily visually distinguishable, even for non-specialists, and specimen collection is not necessary (Figure 1). *Bombus dahlbomii*, the largest bumblebee known, has a predominantly orange ferruginous pilosity completely covering the mesosoma and metasoma, apart from the sixth metasomal tergite, and light brown wings (Figure 1a). Queens are ground-nesting and colonies are small (Montalva et al. 2011). *Bombus terrestris* has yellow dorsal hair on the mesosoma and the rest of the thorax is black. Metasomal tergites 1 and 3 have black hairs, tergite 2 has yellow hairs, and tergites 4 and 5 have white hairs (Figure1b; see also Montalva et al. 2011). *Bombus terrestris* is ground-nesting and colonies are relatively large (up to 500 brood cells; Westphal et al. 2009). The other invasive species, *B. ruderatus* has not been recorded further south than the 71°6′ parallel (Morales et al. 2013: WebTable 1) and although its colors are similar to *B. terrestris* (yellow, black and white), the pattern of colors is completely different. *Bombus ruderatus* has a typically golden-yellow mesosoma with a well-defined black band in the interwing. The metasomal tergite is black and yellow, ending with white hairs. No other native bumblebee species has been reported for Santa Cruz Province (Abrahamovich and Diaz 2001: Figures 1–6), and the second southernmost native bumblebee species in Argentina (*Bombus atratus*) is entirely black (Plischuk et al. 2009: Figure 1). Therefore the risk of confusion with other native or invasive *Bombus* species is negligible. All data were based on personal observations (Geslin pers. obs.). When a specimen was observed, the visited plant was observed for 5 to 10 minutes to count the number of bumblebee individuals.

On 22 December 2014, in the El Chalten locality (49°33′05″ S, 072°88′54″ W) and Camino a lago del Desierto (49°16′24″S, 072°64′32″ W; Figure 2; Table 1) > 10 *B. terrestris* individuals were recorded during a 6-hour walk (Table 1). These two localities represented the southernmost records of individuals of *B. terrestris* in 2011 (Table 1, Morales et al. 2013). In those localities and near them, *B. dahlbomii* was quite abundant in 2011, but no *B. dahlbomii* individuals were recorded on this occasion (Table 1). On 25 December and 31 December 2014, several individuals of *B. terrestris* were recorded in the locality of El Calafate, ca. 150 km south of El Chalten (50°31′21″ S, 072°80′48″ W; Figure 2; Table 1). These represent the first specimens recorded south of the 50° parallel in Argentina, given that in 2011, no *B. terrestris* were

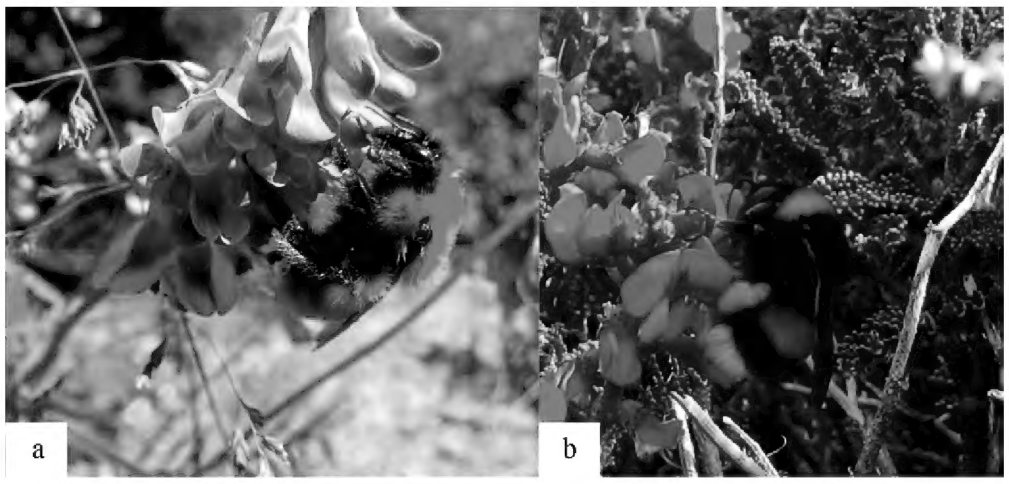

Figure 1. Bumblebees species currently inhabiting Santa Cruz province, Southern Argentina's Patagonia: (**a**) queen of the native *Bombus dahlbomii* foraging on native *Vicia nigricans* and of (**b**) the invasive species *Bombus terrestris* foraging on *Adesmia* sp. (Photos: C. Morales)

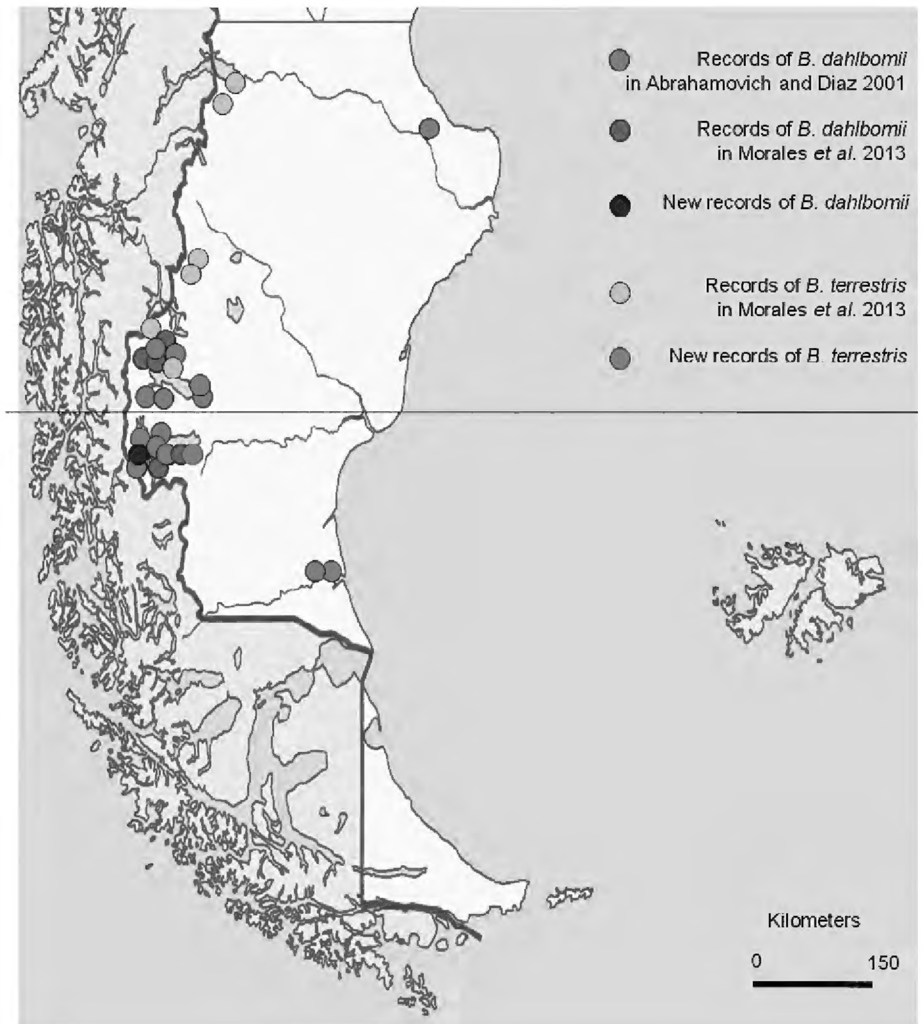

Figure 2. Map of the southernmost part of Argentina's Patagonia, showing the province of Santa Cruz (continental), where all the surveys were done, and the province of Tierra del Fuego (insular). The light-red points represent the southernmost records of *B. terrestris* from the 2011 survey of Morales et al. (2013). The dark red points represent the new records of *B. terrestris*. Thick black line shows the Chilean–Argentine border.

recorded close to the city of El Calafate (Morales pers. obs.) nor in the nearby and more pristine areas of the Parque Nacional Los Glaciares (Morales et al. 2013). Only one specimen of *B. dahlbomii* was observed in the Glaciar Perito Moreno during a 3-hour survey on 25 December 2014, compared to nine observed in 2011 over a slightly longer time interval in 2011 (50°46′35″ S, 073°02′38″ W; Figure 2; Table 1). Finally, around five individuals of *B. terrestris* were recorded in the city of Rio Gallegos in a three-hour survey on 26 December 2014 (51°37′20″ S, 069°12′50″ W; Table 1), ca. 150 km south of El Calafate. They were recorded in a downtown private garden. No specimens of *B. dahlbomii* were observed there, however (Figure 2). Although this area was not surveyed in 2011, historical records reveal the presence of the native species in this area, although there is no information about its historical abundance (Figure 2; see also Abrahamovich and Diaz 2001).

These results extend the southward front of invasion of *B. terrestris* by about 300 km beyond the distribution presented in Morales et al. (2013) (Figure 2). Overall, only one specimen of *B. dahlbomii* was observed during these 7-day naturalist surveys. *Bombus dahlbomii* has been previously described as very abundant in this region, particularly in El Chalten, and its absence is worrying given those past recent records.

These new records of the presence of *B. terrestris* in the southern part of the Argentine Patagonia illustrate the speed of range expansion of this species. In three years, since the last survey (Morales et al. 2013), *B. terrestris* has expended its southward front of invasion by 300 km (i.e., 100 km per year). Schmid-Hempel et al. (2013) estimated the speed of invasion of *B. terrestris* in Argentina and Chile of ca. 200 km/year and predicted that *B. terrestris* would rapidly reach the Strait of Magellan, which is now almost the case. Whether *B. terrestris* will reach the Tierra del Fuego remains unknown and future surveys will have to address this question.

The speed and extent of this invasion raise important concerns about the native populations of *B. dahlbomii*. Populations of this species have strongly declined since the invasion of *B. terrestris*, and some populations have completely disappeared from their historical locations (Morales et al. 2013; Schmid-Hempel et al. 2013). Schmid-Hempel et al. (2013) asserted that when the geographic range of *B. terrestris* increases, that of *B. dahlbomii* decreases in consequence. Comparison of our records with those of 2011 is consistent with these assertions. The observations in 2014 were made earlier in the season than those in 2011, so the abundance of foraging bumblebees observed may be an underestimation, as bumblebee numbers tend to increase over the season (Morales et al. 2013). This underestimation would apply to both *B. dahlbomii* and *B. terrestris*, suggesting that the expansion and population growth of *B. terrestris* may be even stronger than it appears from data comparison.

A southern retreat of cold-adapted species is predicted under expected climate warming. A recent study shows that the suitable climatic conditions for another South American temperate bumblebee species (*B. bellicosus*) will retreat southwards under future climate scenarios (Martins et al. 2014). Although climate warming might play a role in the southward retraction of *B. dahlbomii* (Morales et al. 2013), this alone cannot explain the speed and timing of the species collapse.

Bombus terrestris is a generalist species which forms large colonies and seems to be a strong competitor with *B. dahlbomii*. But the rapid decline of the latter species could also be linked to a transfer of pathogens from *B. terrestris* (e.g., Arbetman et al. 2012). The invasion of *B. terrestris* in Patagonian ecosystems, and linked decline of *B. dahlbomii* may also have consequences for the native flora. Plants species relying on few pollinator species are expected to be more vulnerable to pollinator species extinctions (Memmott et al. 2004). Although *B. terrestris* has been shown to successfully pollinate endemic specialist orchids, which previously relied exclusively on *B. dahlbomii* (Sanguinetti and Singer 2014), the replacement of a native long-tongued by an invasive short-tongued bumblebee may have demographic or evolutionary consequences for many native species with deep corollas like *Alstroemeria aurea* (Alstroemeriaceae) and *Vicia nigricans* (Fabaceae) (Morales and Aizen 2002; Dohzono and Yokohama 2010). In fact, populations of this latter species suffer with high levels of nectar robbing by *B. terrestris* (L. Graham, pers. com.). Montalva et al. (2011) also showed that *B. terrestris* individuals interact preferentially with the non-native plants, which can favor their expansion through pollination service (Simberloff and Von Holle 1999; Memmot and Waser 2002). This is consistent with a growing literature suggesting that pollinator invasions can threaten local plant communities (Hingston et al. 2002; Goulson 2003; Traveset and Richardson 2006; Aizen et al. 2008; Dohzono and Yokoyama 2010).

Moreover, the invasion of *B. terrestris* seems to be detrimental for crop production. A recent publication showed that *B. terrestris* perform extremely high visitation rate on flowers of *Rubus ideaus* (raspberries, Rosaceae) and have negative consequences for crop quality (for example, damaged pistils and reduced fruit set; Saez et al. 2014).

Taken together, these findings illustrate the negative impact that the invasion of *B. terrestris* in the Argentine Patagonia can have for the local fauna, flora and economy. Future conservation efforts on *B. dahlbomii* should urgently focus on preservation of the remaining *B. dahlbomii* populations and ultimately on potential restoration of this species to its former range. To be successful, these measures should not only consider

the control of invasive species and the minimization of habitat disturbance, but also expected future climate scenarios. Current efforts of the Bumblebee Specialists Group launched by the International Union for Conservation of Nature (iucn.org/bumblebees) to assess the extinction risk of the global bumblebee fauna in general and of *Bombus dahlbomii* in particular (Morales et al. in preparation), is a first step in raising attention on this issue. We recommend close monitoring of *B. terrestris*, at least in refuge areas—if such areas still exist—where *B. dahlbomii* is still abundant. This is particularly urgent given the speed of the expansion of *B. terrestris*. Finally, because *B. terrestris* is known to be an aggressively invasive species in many other parts of the world (e.g., Japan [Nagamistu et al. 2007, 2009], Australia [Hingston and McQuillan 1998], and New Zealand [Macfarlane and Gurr 1995]), we strongly discourage future intentional introductions, and urge that agronomical use of this species outside of its native geographic range be avoided.

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